

Evaluation of varietal resistance of commercial sugarcane varieties to stalk borers, *Sesamia* spp. (Lepidoptera: Noctuidae), under field conditions

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Abstract: 【Aim】 The pink stalk borers, *Sesamia* spp., are the most destructive pests of sugarcane, *Saccharum* spp., in Iran and other countries including India, Pakistan, Sri Lanka and Japan. The larvae of *Sesamia* bore into the stalk and cause damage to stalks by reducing weight and sugar content as well as juice quality. For management of stalk borers, several control options are used. Using resistant varieties is an effective tool which has no harmful impact on environment. This study aims to evaluate the resistance of commercial varieties to stalk borers. 【Methods】 The trials were conducted following a randomized block design with five replications in two successive years 2013–2014 and 2014–2015 at Salman-Farsi Agro-industry Farms, Ahwaz, Iran. The eight varieties CP69-1062, CP48-103, CP57-614, CP73-21, SP70-1143, IRC99-01, IRC99-02 and L62-96 were used. Prior to harvest, 20 whole stalks were randomly collected for *Sesamia* spp. damage assessments. Percent of stalks damaged, percent of internodes bored (IB), number of exit holes, number of live *Sesamia* spp. and moth production (MP) per hectare of each variety were recorded. 【Results】 There were significant differences in measured parameters among cultivars. Based on the percent of internodes bored and moth production index, L62-96 was the most susceptible variety among the tested varieties (14.58% IB, 95 200 MP/ha in 2014 and 16.76% IB and 111 300 MP/ha in 2015) followed by CP69-1062 and CP48-103, and CP57-614 was the most resistant cultivar in both years (1.24% IB, 8 400 MP/ha in 2014 and 1.02% IB, 7 000 MP/ha in 2015). 【Conclusion】 We proposed that cultivation of susceptible cultivars should be confined and other control strategies must be incorporated with varietal resistance for management of stalk borers in susceptible varieties.

Key words: *Sesamia* spp.; *Saccharum* spp.; damage assessment; varietal resistance; juice quality; integrated pest management

1 INTRODUCTION

Sugarcane (interspecific hybrids of *Saccharum*) is a strategically important crop that has a profound economic impact on social and governmental issues in many countries around the globe. The most important region for production of sugarcane in Iran is the province of Khuzestan where sugarcane is cultivated on more than one hundred thousand hectares per annum (Sadeghzadeh-Hemayati *et al.*, 2011). This crop is prone to many biotic stressors, and among them lepidopteran stalk-borers are the most destructive and detrimental insect pests of sugarcane in many sugar producing countries except Australia (Long and Hensley, 1972; Sallam, 2006; Goebel and Sallam, 2011). Two species of stalk borers are important in Iranian sugar industry. Both belong to the genus of *Sesamia* (Lepidoptera: Noctuidae), *i. e.*, *S. cretica* (Led.) and *S. nonagrioides* (Lef.). These species can impose economic losses to

commercial varieties and affect sugar industry by both direct and indirect crop damages (Askarianzadeh *et al.*, 2008; Abbasipour and Askarianzadeh, 2010). Stalk borers' infestation can reduce the amount and purity of sugarcane juice and their entrance holes provide entrance window for the red-rot (*Glomerella tucumanensis*) and other pathogens such as *Fusarium* spp. (Showler and Reagan, 2012). The pathogens present in bored stalks contaminate the juice, preventing industrial processes and retarding the production of high-quality sugar crystals (Dinardo-Miranda, 2008). Also, tunneling of stems by larval borer can cause stalks to break and lodge, severe damage may cause desiccation or rotting of mature stalks, development of side or lateral shoots and late tillering (Long and Hensley, 1972) (Fig. 1).

Efficient management of sugarcane moth borers through area-wide integrated pest management programs is multi-strategic and requires that several ecologically and environmentally-sound control methods

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Fig. 1 Damages of pink stalk borers, *Sesamia* spp., on mature cane

A: Internodes bored; B: Moth borer exit hole; C: Side-shooting.

be applied (Rutherford and Conlong, 2010). Among them, crop management, biological control and varietal resistance are the most widely accepted and used around the world for stalk borers (Keeping, 2006; Showler and Reagan, 2012).

Resistant varieties are a powerful part of integrated pest management in sugarcane for *Sesamia* spp. (Askarianzadeh, 2004) as well as for other economically moth borers throughout the sugarcane producing countries (Reay-Jones *et al.*, 2003; Dinardo-Miranda *et al.*, 2012; Wilson *et al.*, 2015). Varietal resistance permits sustainable controls of insect pest populations and is compatible with other control tactics including biological and nutritional management (Keeping, 2006; Rutherford and Conlong, 2010). Moreover, host-plant resistance is an attractive alternative to insecticides, with less cost and environmental side-effects on both human and beneficial arthropods (White *et al.*, 2011). For evaluating the varietal resistance under field and green-house conditions, scientists and sugarcane breeders use parameter of percent of internodes bored and this method is widely accepted (Martin *et al.*, 1975; Keeping, 2006; Dinardo-Miranda, 2008; Ahmad, 2015; Wilson *et al.*, 2015). Percentage of bored internodes has been shown to be inversely correlated with yield parameters including juice purity, tonnage of sugarcane, sugar per ton of cane and sugar per hectare (White *et al.*, 2008; Goebel *et al.*, 2014). This index is widely used on resistance mechanism in early stages of stalk borers. In this criterion, the relationship between crop development and later stages of borers is neglected. In stalk borers, successful life cycle is determined by having a specific exit hole in the whole stalk made by adult moths (Bessin *et al.*, 1990). Moth production index

provides information which might help in management of sugarcane stalk borers' population in an area-wide scenario. The aim of this study provided is to evaluate the resistance to *Sesamia* spp. among commercial sugarcane varieties in Iran using percent of internodes bored, percentage of stalk damage, number of exit holes, and number of larvae and pupae per 100 stalks.

2 MATERIALS AND METHODS

2.1 Trial site, sugarcane varieties and experimental design

Trials were carried out in two successive years 2013–2014 and 2014–2015 at Salman Farsi Agro-industry Farms (48°35'E, 31°8'S), Ahwaz, Iran. Evaluations were established in fields that had a history of stalk borers' infestation. Eight sugarcane varieties, *i. e.*, CP69-1062 (Canal Point USA), IRC99-01 (cross made in Cuba and selected in Iran), IRC99-02 (cross made in Cuba and selected in Iran), SP70-1143 (Sao Paulo, Brazil), CP73-21 (Canal Point USA), CP48-103 (Canal Point USA), CP57-614 (Canal Point USA) and L62-96 (Louisiana USA), were used in the experiment. The characteristics of sugarcane varieties are presented in Table 1. These eight varieties express different levels of resistance to stalk borers under field conditions. The experiments were conducted following a randomized block design with five replications. Each experimental plot (block) consists of six rows, 15 m long and 1.8 m inter-row spaces and 135 m² in different areas of field. This plot configuration was used for our experiments because plots for trials in sugarcane are recommended to be at least 20 m² (Laycock, 2004). All varieties were cultivated under standard tillage, complete plough-out of previous crop remaining, following by ridging

at 1.8 m row spacing through the field. Before planting of sugarcane varieties, phosphorous fertilizer (super phosphate triple/300 kg per hectare) as added with a pneumatic fertilizer machine based on standard management procedures of sugarcane nutrient treatments in Iran. Each sugarcane variety was planted as billets (50 – 60 cm and free from stalk borer infestation) and following planting of seed cane sets all furrows were treated with Atrazine and Sencor herbicides (2 + 2 kg per hectare) based on local recommendations as early post emergence application for suppression of annual weeds. During the vegetative growth of sugarcane, all regrowth weeds were sprayed with systemic herbicide (Glyphosate, only between rows) and the remaining weeds in rows were removed by hand. Neither insecticides nor releasing egg parasitoids (*Telenomus busseolae* Gahan) were applied in each experimental plot.

Table 1 Characteristics of sugarcane varieties applied in the experiments

Variety	Origin, organization & country	Maturity
L62-96	Louisiana, LSU, USA	Late maturing
CP48-103	Florida, Canal Point, USA	Middle-late maturing
CP69-1062	Florida, Canal Point, USA	Middle maturing
CP73-21	Florida, Canal Point, USA	Early maturing
SP70-1143	São Paulo, Usina da Barra, Brazil	Early maturing
IRC99-01	Iran, ISCRTI & INICA, Iran-Cuba	Early maturing
CP57-614	Florida, Canal Point, USA	Early maturing
IRC99-02	Iran, ISCRTI & INICA, Iran-Cuba	Late maturing

2.2 Sampling procedures and data collected

Prior to harvest time of each variety, 20 whole stalks were randomly collected from the two central rows of each experimental plot (Reay-Jones *et al.*, 2005) for *Sesamia* spp. damage assessments. The leaves of all stalks were completely removed (at the natural breaking point after the last fully expanded internode). The number of internodes per stalk, number of internodes bored per stalk, number of moth borer exit holes, percentage of stalks damaged (number of stalks sampled bored per plot/total number of stalks sampled per plot × 100), percentage of internodes bored (number of

internodes sampled bored per plot/total number of internodes sampled per plot × 100), number of live borers per stalk expressed as *Sesamia* larvae or pupae per stalk, S/100 (in each plot leaf sheaths of selected stalks were removed to find larvae or pupae, and each infested stalk longitudinally dissected and the number of larvae were recorded) and adult moth emergence per hectare were determined and calculated. In accordance with the method of Bessin *et al.* (1990) and Reay-Jones *et al.* (2003), moth production per hectare was calculated as the number of moth borer adult exit holes per stalk multiplies the stalk density per hectare. Because of small plot size in our trials, a density of 70 000 stalks per hectare for all the tested varieties was applied.

2.3 Data analysis

All data were analyzed for normality and homogeneity of variance (Bartlett’s test), and appropriate transformations [ArcSin or log (*x* + 1)] were applied where these conditions were not met, before analysis of variance was performed. All analysis was performed with SPSS software version 16 (SPSS, 2007). Tukey’s honestly significant difference (HSD) test was used for means separations between treatments at 0.05 significance levels. Untransformed means and standard errors are shown in the tables.

3 RESULTS

Percentage of *Sesamia* spp. stalk damage was significantly higher in L62-96, followed by CP48-103 and CP69-1062 varieties in 2014. However, CP57-614 indicated low level of stalk damage. Also, the most internodes bored, number of exit holes per stalk and number of larvae and pupae per 100 stalks were observed in L62-96 variety. The least moth production was recorded in CP57-614 and IRC99-02 indicating resistance of the varieties (Table 2).

Similar results were obtained in 2015, indicating that L62-96 variety obtained the most damage from *Sesamia* spp. infestation with 61% stalk damage, 16.76% internodes bored, 1.59 exit holes/stalk and 111 300 moth production/ha. In contrast, CP57-614 variety showed the most resistance to the infestation (Table 3).

Table 2 Assessment of *Sesamia* spp. damage and varietal resistance of sugarcane in Ahwaz, Iran in 2014

Variety	% Stalks damaged	% Internodes bored	Number of exit holes/stalk	S/100	Moth production/ha
L62-96	49 ± 1.87 a	14.58 ± 0.19 a	1.36 ± 0.02 a	49 ± 1.87 a	95 200 ± 1.31 a
CP48-103	37 ± 1.22 b	7.74 ± 0.13 c	0.67 ± 0.02 c	31 ± 1.87 c	45 500 ± 1.56 c
CP69-1062	39 ± 1.04 b	11.64 ± 0.22 b	1.01 ± 0.04 b	39 ± 1.08 b	70 700 ± 2.8 b
CP73-21	17 ± 1.22 cd	2.22 ± 0.11 e	0.21 ± 0.03 e	16 ± 1.08 e	14 700 ± 2.04 e
SP70-1143	27 ± 1.22 c	4.34 ± 0.11 d	0.43 ± 0.02 d	23 ± 1.22 d	30 100 ± 1.4 d
IRC99-01	18 ± 1.22 c	2.12 ± 0.12 e	0.22 ± 0.02 e	16 ± 1.08 e	15 400 ± 1.78 e
CP57-614	11 ± 1.04 e	1.24 ± 0.04 f	0.12 ± 0.01 e	10 ± 1.58 e	8 400 ± 8.57 f
IRC99-02	12 ± 1.22 de	1.48 ± 0.12 f	0.13 ± 0.01 e	11 ± 1.87 e	8 820 ± 1.05 f
<i>F</i> _{7,32} , <i>P</i>	121.8, 0.000	1 338.9, 0.000	355.9, 0.000	90.9, 0.000	355.9, 0.000

Means followed by different letters in each column are significantly different using Turkey’s test at *P* < 0.05.

Table 3 Assessment of *Sesamia* spp. damage and varietal resistance of sugarcane in Ahwaz, Iran in 2015

Variety	% Stalks damaged	% Internodes bored	Number of exit holes/stalk	S/100	Moth production/ha
L62-96	61 ± 1.04 a	16.76 ± 0.07 a	1.59 ± 0.02 a	57 ± 2.07 a	111 300 ± 1.32 a
CP48-103	36 ± 1.87 b	7.02 ± 0.12 c	0.61 ± 0.04 c	31 ± 1.06 c	42 700 ± 2.58 c
CP69-1062	42 ± 1.22 b	12.06 ± 0.11 b	1.04 ± 0.05 b	40 ± 2.73 b	72 800 ± 3.58 b
CP73-21	16 ± 1.87 de	1.92 ± 0.15 e	0.17 ± 0.01 e	15 ± 1.58 de	11 900 ± 8.5 e
SP70-1143	27 ± 1.22 c	4.28 ± 0.24 d	0.45 ± 0.02 d	25 ± 1.58 c	31 500 ± 1.57 d
IRC99-01	18 ± 1.22 d	2.02 ± 0.06 e	0.19 ± 0.01 e	16 ± 1.87 d	13 300 ± 7 e
CP57-614	9 ± 1.04 f	1.02 ± 0.13 f	0.1 ± 0.02 e	8 ± 1.22 e	7 000 ± 1.11 f
IRC99-02	11 ± 1.87 ef	1.18 ± 0.11 f	0.11 ± 0.01 e	9 ± 1.06 de	7 700 ± 7 f
<i>F</i> _{7,32} , <i>P</i>	150.7, 0.000	1 910.0, 0.000	423.9, 0.000	97.7, 0.000	423.9, 0.000

Means followed by different letters in each column are significantly different using Turkey’s test at *P* < 0.05.

4 DISCUSSION AND CONCLUSION

Crop resistance is a fundamental part of an integrated pest management system, mainly against moth borers in sugarcane agro-ecosystem (Reay-Jones *et al.*, 2003; Keeping, 2006; Wilson *et al.*, 2015). Our research evaluated the resistance to *Sesamia* spp. in eight commercial varieties over two consecutive years based on crop infestation (internodes bored and stalk damage) and survival (moth production per hectare). The results indicated that there were significant variations among the tested varieties. In a one-year trial, Abbasipour and Askarianzadeh (2010) evaluated the damage of stalk borers on different varieties based on dead-heart and bored internodes. At harvest, they showed that the damage pattern was different among varieties and CP69-1062 was more susceptible with 27 percent of bored internodes followed by CP48-103, SP70-1143 CP73-21 and CP57-614. The results of our two-year trials were in accordance with them, but we found more damage on L62-96 which was the most susceptible among the tested varieties. In United States, Martin *et al.* (1975) showed that CP48-103 and L62-96 was susceptible to sugarcane borer, *Diatraea saccharalis* (F.), but percent of bored internodes in CP48-103 was higher than that in L62-96. In our two-year trials, L62-96 was the most susceptible variety under natural infestation of genus of *Sesamia* spp., and this contradiction may be in relation to different species of moth borer. In our research, we tested two Iranian-Cuban varieties, and found different levels of resistance among them. Assessment of plant damage and varietal resistance based on percent of bored internodes is widely accepted by many researchers (Nuss, 1991; Keeping and Rutherford, 2004; Askarianzadeh *et al.*, 2008). In Brazil, Dinardo-Miranda *et al.* (2012) tested ten commercial varieties against *D. saccharalis* and found that there were significant differences among varieties based on percents of bored internodes. The authors concluded that IACSP94-2094 was the most resistant and IACSP94-4004 was the most susceptible.

Adult emergence holes represent a seasonal record

of moth production from sugarcane and might assist in choosing a cultivar that would suppress moth borers and in our study *Sesamia* spp. populations on an area wide basis (Reay-Jones *et al.*, 2003). In a three-year field experiments, Bessin *et al.* (1990) evaluated varietal resistance of sugarcane cultivars to sugarcane borer, *D. saccharalis*. They found that there were significant differences among the tested varieties based on percent of bored internodes and moth production index. Among the varieties, CP61-37 was the most susceptible, with 32.8%, 39.9% and 44.8% bored internodes and 32 267, 69 551 and 59 604 moth production per hectare from 1985 to 1987. In another study, Reay-Jones *et al.* (2003) assessed the resistance to Mexican rice borer, *Eoreuma loftini* (Dyar) among sugarcane varieties in Texas and Louisiana. The authors showed that HoCP85-845 was the most resistant variety with 5.29% and 4.94% of bored internodes and 3 038 and 4 197 moth emergence per hectare in 2001 and 2002, respectively. In a new study, Wilson *et al.* (2015) investigated varietal resistance against *E. loftini* from 2009 to 2012. In relation to percent of bored internodes and survival to adult stage, they found different resistance levels among varieties. Among the tested varieties, HoCP85-845 was recorded as resistant and HoCP04-838 was identified as susceptible cultivar. The results of our study indicated that the levels of resistance among the tested varieties were different based on percent of bored internodes and moth production index. The variety L62-96 was the most susceptible among varieties and the cultivation of this cultivar has increased. We suggest that cultivation of L62-96 should be confined and other control methods including releasing parasitoids, silicon treatment and even application of selective insecticides are recommended in fields under cultivation of this variety.

In conclusion, continued assessment of varietal resistance to *Sesamia* spp. is crucial to implement an effective integrated management tactics for pink stalk borers.

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田间条件下甘蔗品种对蛀茎夜蛾的抗性评价

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摘要:【目的】蛀茎夜蛾 *Sesamia* spp. 是伊朗和其他国家(包括印度、巴基斯坦、斯里兰卡和日本)甘蔗上最具破坏性的害虫。蛀茎夜蛾幼虫钻蛀茎秆,对茎秆产生为害,降低重量和含糖量并降低甘蔗汁品质。应用抗性品种是一种有效的工具,对环境无不利影响。本研究旨在评价甘蔗商业品种对蛀茎夜蛾的抗性。【方法】在伊朗 Ahwaz 的 Salman-Farsi Agro-industry Farms 于 2013–2014 和 2014–2015 两个连续年份,采用随机区组设计进行 5 次重复试验。应用了 CP69-1062, CP48-103, CP57-614, CP73-21, SP70-1143, IRC99-01, IRC99-02 和 L62-96 8 个品种。在收获前,随机取 20 株完整的甘蔗茎秆进行蛀茎夜蛾的为害评估。记录受害茎秆百分比、被钻蛀的节间百分比(percent of internodes bored, IB)、出口孔的数目、活的蛀茎夜蛾的数目、每品种每公顷面积中蛾的繁殖量(moth production per hectare of each variety, MP)。【结果】各测定参数在品种间均存在显著差异。从被钻蛀的节间百分比和蛾的繁殖指数判断,L62-96 是最敏感的品种(2014 年:14.58% IB, 95 200 MP/ha; 2015 年:16.76% IB 和 111 300 MP/ha),其次是 CP69-1062 和 CP48-103; CP57-614 是这两年中抗性最强的品种(2014 年:1.24% IB, 8 400 MP/ha; 2015 年:1.02% IB, 7 000 MP/ha)。【结论】建议限制敏感品种的栽培,并应用其他控制措施,结合品种抗性,以治理敏感品种中的蛀茎夜蛾。

关键词: 蛀茎夜蛾; 甘蔗; 为害评估; 品种抗性; 果汁品质; 害虫综合治理

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